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Florida International University

January 10, 1994

Office of the Secretary
Federal Communications Commission
Washington, D. C. 20554

Dear Secretary:

I have enclosed ten copies of my comments regarding ET Docket No. 93-62, "Guidelines for Evaluating the Environmental Effects of ~~Radiof~~requency Radiation", which is currently before the Federal Communications Commission. I wish to have these written comments filed formally, and am sending a total of ten copies so that each Commissioner may have a personal copy. I would appreciate your filing and distributing my written comments, and wish to thank you for this service.

Sincerely,

Mark J. Hagmann
Associate Professor
Phone 305-348-3017
FAX 305-348-3707

No. of Copies rec'd 0+9
List A B C D E

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Comments on ET Docket No. 93-62
Before the Federal Communications Commission
Guidelines for Evaluating the Environmental
Effects of Radiofrequency Radiation

by Professor Mark J. Hagmann
Department of Electrical and Computer Engineering
Florida International University, Miami, FL 33199
January 10, 1994

I wish to make several comments regarding why I feel that the proposed ruling should not be put into effect. I agree that it is necessary to evaluate environmental factors including human exposure to RF radiation from FCC-regulated transmitters and facilities, but I do not believe that adopting the standard designated ANSI/IEEE C95.1-1992 would be a valid step toward accomplishing this goal.

As background, I should state that I have studied various aspects of the biological effects of electromagnetic fields as my research specialty for the past 18 years. I have had more than 50 publications on this subject in peer-reviewed journals and have given more than 130 presentations at international conferences. I have served on IEEE SCC28, ANSI C95.4, and the U. S. Army FEL Hazards Advisory Panel. I have been an expert witness in both county and federal courts, and was called to testify on the biological hazards of electromagnetic fields before the Committee on Environment and Public Works of the U. S. Senate.

1. I object to the treatment of induced RF currents.

The 1992 ANSI/IEEE guidelines contain new recommendations regarding the maximum permissible exposure from induced and contact RF currents. This is an important topic that was not addressed in the former ANSI guidelines. However, I believe that A) there is bias favoring one type of instrument, B) limiting current measurements to the point of entry on the human body is not appropriate, C) the upper frequency limit for current measurements is not appropriate, and D) there is a relevant conflict of interest in the leadership of IEEE Standards Coordinating Committee 28. These four points are treated in the following paragraphs.

A) There is bias favoring one type of instrument.

Three different methods for determining currents are described in the standards document [1].These are RF thermocouple-type ammeter measurements, voltage measurements across a series resistor, and RF current transformers measurements. The description on pp. 18-19 of the standards document appears to be biased in favor of the second procedure, voltage measurements across a series resistor.

Paragraph (a) describing RF thermocouple-type ammeters ends with the sentence "While simple in design and use, thermocouple-type ammeters have very limited tolerance for overload currents that can destroy the thermocouple element." Later on p. 19 it is stated that "thermocouple detectors used in some RF ammeters exhibit variations in their response to different frequencies". These comments would tend to discourage purchasing this type of instrument for the purpose of determining compliance.

Paragraph (b) describing voltage measurements across a series resistor fails to mention that the stand-on devices used to measure induced currents are field sensitive, having an anomalous response when there is no human subject. Blackwell observed [2] that the metal plate of a stand-on device causes appreciable errors in the measured current. In recent tests I found that the currents measured with a stand-on current meter made by Holaday do not correlate with those determined with a standard current transformer. For example, at 60 MHz with vertical polarization the reading with the Holaday meter alone (no human subject) was approximately twice that with a human volunteer. Paragraph (b) ends with the sentence "Commercial instruments with a flat frequency response between 3kHz and 100 MHz are beginning to become available for this purpose ... ". This statement, which has doubtful accuracy in view of my observations and those of Blackwell, would tend to encourage purchasing this type of instrument for the purpose of determining compliance.

Paragraph (c) describing RF current transformers specifies that these devices "may be used to determine the current flowing in a parallel plate electrode arrangement, as described in (b), or in conjunction with a conductive rod probe assembly to determine contact currents that might be experienced by a person touching an object exposed to RF fields." Paragraph (c) fails to note one of the main advantages of current transformers, in that they can also be placed on the arm, torso, leg, neck, etc. in order to determine local values of current. It is not necessary to use a stand-on device with an RF current transformer so there is no anomalous reading when the human subject is removed [2],[3]. Later on p. 19 it is stated that " ... current transformer performance characteristics are a compromise between sensitivity and bandwidth." It is not mentioned that current transformers are available for use in various frequencies ranges, from below 60 Hz to over 1 GHz.

B) The specified measurement locations are inappropriate.

As we have already noted, current transformers can be placed on the arm, torso, leg, neck, etc. in order to determine local values of current in the human body. This could not be done with RF thermocouple-type ammeter measurements or with voltage measurements across a series resistor, so the latter two types of measurements may only be used to determine the current at the point where it enters the human body (e.g. with a stand-on device). Nevertheless, the standard specifies limiting values of the foot current as the criterion for induced currents and, as previously noted, limits the use of current transformers to "determine the current flowing in a parallel plate electrode arrangement, as described in (b), or in conjunction with a conductive rod probe assembly to determine contact currents ..."

It is known that the current density at some locations in the body exceeds that between the feet and ground. For example, numerical simulations made by Professor Gandhi's group [4] suggest that heating may be maximum in the ankles. Other simulations suggest that the current is maximum in the thighs, because some of the current is coupled capacitively to ground (displacement current) rather than being conducted through the feet. Furthermore, the current has a node at the feet if the person is isolated from the ground. For these reasons it seems reasonable to use current transformers to determine local values of current instead of using a stand-on device. Limiting the measurements to a stand-on device also prevents making useful measurements in many practical situations such as when a technician climbs an antenna tower or when workers are standing on thick layers of wood or other non-conductive material.

C) The upper frequency limit is inappropriate.

Others have already noted [5] that specifying the upper frequency for current measurements as 100 MHz is inconvenient because this frequency is located in the middle of the FM broadcast band. I have already mentioned that the stand-on devices used to measure induced currents are field sensitive, having an anomalous response when there is no human subject. I have observed that the sensitivity to fields increases with frequency, as would be expected from antenna theory.

I do not know the basis for specifying that current measurements be made only below 100 MHz, but this requirement is consistent with limitations of the stand-on devices. Also, the relationship between foot current and currents elsewhere in the human body becomes more complex as the frequency is increased, so foot current measurements would have little predictive value at frequencies above 100 MHz. As we have already mentioned, current transformers are available for use in various frequencies ranges, from below 60 Hz to over 1 GHz. We have used non-ferrous current probes to determine the current in the human leg at frequencies as high as 200 MHz [3].

D) There is a relevant conflict of interest in the leadership.

Section 2 of the IEEE code of ethics, which may be found in the IEEE Policy and Procedures Manual, states that members of the IEEE agree "to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist." It appears that IEEE Standards Coordinating Committee 28 had no written bylaws or operating procedures at the time that the standards were written. In fact, the bylaws were only recently submitted to the IEEE, and have not yet been approved [6]. However, I would hope that the code of ethics agreed to by the membership of the IEEE would be followed by the committee.

Professor Gandhi is a Co-Chair of IEEE Standards Coordinating Committee 28, and served in this capacity when the standards document was prepared and disseminated. Professor Gandhi holds patents on probes for determining the current in the human body by voltage measurements across a series resistor such as with a stand-on device (e.g. U. S. 4,672,309 issued June 1987). I am familiar with the patent policy at the University of Utah, and feel safe in assuming that both he and his university would profit from the sales of current probes made under license agreements pertaining to his patents. The current probes which Professor Gandhi has patented are sold by Narda Microwave (e.g. Loral Microwave-Narda catalog models 8850/8850A and others) [7]. Since current probes are required for determining compliance with the standard, I feel that having Professor Gandhi act as the Co-Chair of the committee violates the dictum "to avoid real or perceived conflicts of interest whenever possible". Furthermore, I have spoken with several members of IEEE Standards Coordinating Committee 28 who were unaware of Dr. Gandhi's patents (e.g. D. E. Ericksen, W. Sidas and M. Rose), so it appears that there was also a failure "to disclose them to affected parties when they do exist."

It is my opinion that the standard designated ANSI/IEEE C95.1-1992 is invalid because of the conflict of interest among the leadership of the committee which prepared it. This conclusion is independent of whether or not the standard is intentionally biased because of this conflict of interest. I believe that the stand-on current probe sold by Holaday is not made under a license agreement for Professor Gandhi's patents. However, whether or not Narda Microwave is a sole source does not alter the fact that both Professor Gandhi and his university would profit from the sales of current probes purchased in order to determine compliance with the standard made by the committee for which he was a Co-Chair.

I must state that I am a co-inventor of another current probe that is intended for use in dosimetry (e.g. U. S. 4,913,153 issued April 1990). It is my opinion that the bias which I have pointed out in the standard would cause Professor Gandhi to have an unfair advantage in the sales of his current probes, which would result in a financial loss to both me and my university. However, unlike Professor Gandhi, I did not serve as a leader in the committee and did not participate in preparing or disseminating the standard.

On August 17, 1993 I wrote a letter to the IEEE Standards Board (Appendix I) listing some of the objections made in the present written comments. I received a response from Susan Valinoti dated August 25, 1993 (Appendix II). No response has yet been received from the committee.

2. I question the operating procedures of the committee.

It appears that IEEE Standards Coordinating Committee 28 had no written bylaws or operating procedures at the time that the standards were written. In fact, the bylaws were only recently submitted to the IEEE, and have not yet been approved [6]. John D. Parisi, IEEE Staff Engineer for the IEEE Standards Department, has told me that in the absence of bylaws the committee should have followed the more general bylaws [8] and operations manual [9] of the IEEE Standards Board.

The following is quoted from p.18 of the IEEE Standards Board Operations Manual [9]:

> If an IEEE standards-developing committee chooses to use patented technology in its standard, it is essential that the committee cite the reasons why such technology needs to be incorporated into the standard. In addition, alternative technologies should be identified that achieve the same end, along with the advantages and disadvantages of that alternative technology. This information shall be placed on file in the IEEE Standards Department. The record should be written in the context of who the proponents are of the patented technology and the interests that they may have in the adoption of the particular technology. Further, statements that assess the alternatives to patented technologies shall be structured to indicate a) if these alternatives will satisfy the public need, and b) if the use of the patented technology will exclude any segment of the relevant industry from meaningful competition.

I would conclude that the standard designated ANSI/IEEE C95.1-1992 was prepared in violation of the operations manual for the IEEE Standards Board because although this standard refers to patented technology it is not clear that there was a record as to "who the proponents are of the patented technology and the interests that they may have in the adoption of the particular technology." I have already stated that several members of IEEE Standards Coordinating Committee 28 were unaware of Professor Gandhi's patents (e.g. D. E. Ericksen, W. Sidas and M. Rose). Furthermore, in my opinion the limited description of the advantages and disadvantages of the alternative technologies (i.e. the three types of current measurement) which I have cited in these comments demonstrates a neglect to determine "a) if these alternatives will satisfy the public need, and b) if the use of the patented technology will exclude any segment of the relevant industry from meaningful competition."

There is a list of the membership of IEEE Standards Coordinating Committee 28 at the time that the standard was prepared on p. 4 of the standards document [1]. According to this list I was a member of the committee. However, in the absence of written bylaws or operating procedures for the committee I have studied both the general bylaws [8] and operations manual [9] of the IEEE

Standards Board and am still puzzled as to what constitutes membership in the committee. I attended several meetings of the committee and received announcements of meetings, but I never wrote anything for the committee, or was asked for my opinion on any draft of the standard. Still I am credited on the standards document which implies that I participated in drafting the standard. I asked several others (e.g. D. E. Ericksen, T. M. Babij and C. F. Gottlieb) what constituted membership in the committee, and how the leadership was elected or appointed and they said that they did not know either. I do not know how a standards document can be taken seriously if the operating procedures of the committee are not properly defined.

Mark J. Hagmann
January 10, 1994

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1. IEEE Standards Coordinating Committee 28, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE C95.1-1991, New York, IEEE, 1992.

2. R. P. Blackwell, "The Personal Current Meter--A Novel Ankle-Worn Device for the Measurement of RF Body Current in a Mobile Subject," J. Radiol. Prot. (UK), Vol. 10, June 1990, pp. 109-114.

3. M. J. Hagmann and T. M. Babij, "Noninvasive Measurement of Current in the Human Body for Electromagnetic Dosimetry," IEEE Transactions on Biomedical Engineering, Vol. 40, May 1993, pp. 1-6.

4. O. P. Gandhi, I. Chatterjee, D. Wu and Y.-G. Gu, "Likelihood of High Rates of Energy Deposition in the Human Legs at the ANSI Recommended 3-30 MHz RF Safety Levels," Proceedings of the IEEE, Vol. 73, June 1985, pp. 1145-1147.

5. Federal Communications Commission, "Notice of Proposed Rule Making," FCC 93-142, p. 10.

6. J. D. Parisi, IEEE Staff Engineer, IEEE Standards Department, Personal Communication.

7. E. Aslan, Narda Microwave, Personal Communication.

8. IEEE Standards Board, IEEE Standards Board Bylaws, New York, IEEE, 1992.

9. IEEE Standards Board, IEEE Standards Operations Manual, New York, IEEE, 1993.

Florida International University

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August 17, 1993

Secretary, IEEE Standards Board
445 Hoes Lane
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Dear Secretary:

Your committee, of which I am a member, has issued two standards documents specifying limits for safe human exposure to non-ionizing radiation [1], and the practices for measuring potentially hazardous electromagnetic fields [2]. Objectivity is essential to the preparation of such documents because they state the policy of our society (IEEE) on a matter of public health and safety at a time when there is much public concern, and considerable disagreement within the bioeffects community as to what is and is not safe. This letter was written to address several topics on which the documents appear to lack objectivity.

1. Internal parameters should be given greater emphasis.

The limits for human exposure are specified [1] in terms of what may be called "external" and "internal" parameters. The external parameters include the incident electric and magnetic field strengths, while the internal parameters include the current and SAR (specific absorption rate). The internal parameters of current and SAR are generally believed to correlate with the physiological effects of exposure. Nevertheless, external parameters are commonly used to characterize the exposure with the justification that 1) they are more convenient to measure, and 2) they are related to the internal parameters. In fact, the transfer function is incompletely-characterized but is known to depend on the height, weight, and pose of the subject, the proximity of the subject and/or source to various objects, and the frequency, polarization, and other properties of the source.

2. The documents should specify that current transformers may be used for measurements at various locations in the body.

Since several researchers described the use of RF current transformers to measure induced current at various locations in the body (rather than only between the feet and ground) prior to publication of the two IEEE standards documents, it is surprising that this method was not included in the specifications, or otherwise addressed in the documents. In 1986 Gronhaug first de-

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scribed his use of RF current probes for measurements in the arms and legs of human subjects in EMP simulations [3],[4]. In 1987 I first described the use of non-ferrous RF current probes to measure induced currents in the arms and legs of human subjects and tissue-simulating figurines [5]-[8]. In 1990 Blackwell published a description of an ankle-worn current probe as a dosimeter [9], and he described current measurements at meetings of the Bioelectromagnetics Society in 1987 and 1988.

3. <u>Both documents specify that induced currents be measured between the feet and ground, and limit the upper frequency for these measurements to 100 MHz</u>.

IEEE Standard C95.1-1991 gives maximum permissible limits for the induced current through the feet at frequencies from 3 kHz to 100 MHz (pp. 13-15), and specifies (p. 18) that "<u>Induced body currents should be measured by determining the RF current flowing to ground through the feet of the individual</u>." The document states (pp. 17-18) that the foot to ground current may be determined by either voltage measurements across a series resistor, RF thermocouple-type ammeters, or RF current transformers, but only describes the use of current transformers as follows; "Current transformers may be used to determine the current flowing in a parallel plate electrode arrangement ... or in conjunction with a conductive rod probe assembly to determine contact currents that might be experienced by a person touching an object exposed to RF fields."

IEEE Standard C95.3-1991 also specifies that induced currents be measured between the feet and ground, and mentions the use of RF current transformers only for measurements in a conductor between the feet and ground (p. 71). This standard states (p. 13) that "The issue of induced body currents generally becomes a consideration at lower frequencies, typically below 100 MHz, and especially below 30 MHz."

4. <u>Limiting the determination of induced currents to measurements between the feet and ground, and to frequencies below 100 MHz, is unnecessary and decreases their value for dosimetry.</u>

Numerical simulations suggest that measurements of the current between the feet and ground have some (limited) value for predicting the induced currents elsewhere in the body with vertical polarization at frequencies below approximately 100 MHz when the person has a fixed vertical pose and the shoes are in contact with a reasonably good ground plane. The numerical simulations predict that even under these optimal conditions the current is typically about 20 percent greater in the calves than at the feet.

Current transformers have been used to measure the induced current at locations other than between the feet and ground. It appears more straightforward to measure the current in the calves, and to determine maximum, rather than to make inferences from measured currents between the feet and ground. If a person is isolated from ground (e.g. standing on a wood scaffold) it would be unreasonable to connect him to ground to determine the current. In this case the current would have a null at the feet, so a current transformer would be more appropriate.

Any object placed between the feet and ground will cause some change in the induced currents. Blackwell observed [9] that stand-on current meters increase the total height, which causes a small change in the current. Blackwell also observed [9] that the metal plate of a stand-on current meter alters the current flow. His measurements showed that this effect can either increase or decrease the measured current. In recent tests (unpublished) with a stand-on current meter made by Holaday I found that at 60 MHz with vertical polarization, the reading with a human volunteer was approximately one-half that with no subject.

RF current is a measure of the potential for shock, burn and cell stimulation [1, p. 32], but additionally the current is related to the SAR through the known dielectric properties of tissues. At the present time RF current transformers appear to be the best way of estimating the SAR distribution noninvasively. Non-ferrous RF current transformers may be used to measure the current at frequencies as high as 450 MHz in a small region such as the wrist or ankle, or 150 MHz in the human torso.

5. <u>IEEE standards documents should not refer the reader to commercial instruments, or should make impartial references to all related devices.</u>

IEEE Standard C95.1-1991 contains the following comment (p. 19) regarding stand-on current meters which may serve as an invitation to the consumer; "Commercial instruments with a flat frequency response between 3 kHz and 100 MHz are beginning to become available for this purpose ..." While none of the limitations of the stand-on meters are described, the following comment is made regarding a competitive instrument; "While simple in design and use, thermocouple type ammeters have very limited tolerance for overload currents that can destroy the thermocouple element."

IEEE Standard C95.3-1991 contains a paragraph (p. 71) concerning stand-on current meters, of which we quote the first and last sentences; "Chen and Gandhi have described a parallel plate type of system in the form of a bi-layered printed circuit board, in the shape of the human feet, upon which one stands to determine the foot current. ... Commercial instruments with a flat frequency response between 3 kHz and 100 MHz are available, as are shoe-insertable sensors."

The stand-on current meter referred to in both standards documents was patented by Professor Gandhi, the Co-Chair of C95.1 at the time the IEEE standards were published. This meter is listed as Model 8850/8850A in the Loral Microwave-Narda catalog. The Model 8854 I-Mat is a variant of this device. I believe that the Model 8870/8870A Contact Current Meters are also his invention and are overly consistent with the specifications for measurement of contact current in the IEEE standards. I object to the obvious conflict of interest of having a person in a leadership position on a standards subcommittee who can profit financially from the decisions of that committee.

In summary, I find that the two standards documents contain specifications for measurements of induced current that appear to be 1) overly restrictive, thus limiting their value for dosimetry, and 2) consistent with the limitations of commercial current probes patented by the Co-Chair of C95.1. Furthermore, both documents contain specific references to the availability of the commercial devices, and a description of the limitations of at least one competing instrument with no indication of the limitations of the stand-on current meters. I would appreciate your attention in having these matters corrected, and look forward to hearing from you.

Sincerely,

Mark J. Hagmann
Associate Professor
305 348-3017

References

1. IEEE Standards Coordinating Committee 28, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE C95.1-1991, New York, IEEE, 1992.

2. IEEE Standards Coordinating Committee 28, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields--RF and Microwave, IEEE Std C95.3-1991, New York, IEEE, 1992.

3. K.-L. Gronhaug, Measurements and Calculations of Current Induced in a Human Body by EMP Illumination, FFL/NOTAT-86/4008, Norwegian Defence Research Establishment, 1986.

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5. M. J. Hagmann and T. M. Babij, "Methods for Determining SAR from Noninvasive Measurements," Invited Presentation at the IEEE Engineering in Medicine and Biology Society Ninth Annual Conference, Boston MA, November 13-16, 1987.

6. M. J. Hagmann and T. M. Babij, "Device for Non-Perturbing Measurement of Current as a Dosimeter for Hyperthermia," North American Hyperthermia Group Meeting, Philadelphia PA, April 16-21, 1988.

7. T. M. Babij and M. J. Hagmann, "Noninvasive Measurement of RF Current for Dosimetry," Bioelectromagnetics Society Meeting, Stamford CT, June 19-24, 1988.

8. M. J. Hagmann and T. M. Babij, "Noninvasive Measurement of current in the Human Body for Electromagnetic Dosimetry, IEEE Transactions on Biomedical Engineering, Vol. 40, May 1993, pp. 1-6.

9. R. P. Blackwell, "The Personal Current Meter--A Novel Ankle-Worn Device for the Measurement of RF Body Current in a Mobile Subject," J. Radiol. Prot. (UK), Vol. 10, June 1990, pp. 109-114.

IEEE STANDARDS DEPARTMENT
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TO: Dr. Thomas Budinger, SCC28 Chair
Dr. John Osepchuk, SCC28 Executive Secretary

FROM: Susan Vallnoti, SCC28 Secretary *Susan Valinoti*

DATE: 25 August, 1993

RE: Request for Interpretation

Mark J. Hagmann, Associate Professor, of the Department of Electrical & Computer Engineering, College of Engineering & Design has written the IEEE Standards Board requesting an interpretation of IEEE C95.1-1991 and IEEE C95.3-1991 standards. The Standards Board therefore requests the leadership of the standards developing committee (Standards Coordinating Committee 28, SCC28) to form a balanced interpretations committee to address Mr. Hagmann's questions on information covered in the IEEE C95.1 and C95.3 Standards in accordance with the IEEE Standards Operations Manual, Section 5.9 on Interpretations.

Please contact me at (908) 562-3810, if you should have any questions or comments.

SV/tf
cc: T. deCourcelle, Manager Standards Board Technical Support
C95.1 and C95.3 Project Files
A. Salem, Secretary IEEE Standards Board
Mark J. Hagmann, Associate Professor - College of Engineering & Design

Attachments:

Section 5.9 IEEE Standards Operations Manual
Request for Interpretation